# COMPRESSION COOLING SYSTEM AND METHOD FOR EVALUATING OPERATION THEREOF

## BACKGROUND OF THE INVENTION

The present invention is directed to compression conditioning systems, and especially to a vapor compression conditioning system, such as a heat pump or air conditioner, that does not require breaching the system to evaluate operation of the system, such as for evaluating state of charge of refrigerant in the system.

Proper charge of refrigerant is a crucial requirement for maintaining efficient operation of a compression cooling system. Servicemen visit cooling systems on-site in order to check refrigerant level and to refill or recharge systems that are found to have a low refrigerant charge. Typical measurements performed by a service representative in checking a system involve hauling heavy, unwieldy pressure gauges to the condenser unit of the system (usually located outside the cooled premises, such as on a roof or in a yard). The pressure gauges are hooked up to the refrigerant line of the cooling system so that pressure in the refrigerant fluid line may be measured. This connection of pressure gauges necessarily involves breaching the cooling system, which involves a risk that the sealed nature of the system may be compromised and refrigerant may be lost to the atmosphere. The serviceman also measures temperature of the refrigerant in its liquid state. Then a table or other reference is consulted by the serviceman using his pressure and temperature measurements to determine the amount of refrigerant needed to configure the cooling system for efficient operation.

It would be useful for the serviceman to be able to more straightforwardly check condition of the cooling system without having to breach the system and risk losing refrigerant.

If checking of the refrigerant level could be carried out automatically, then results of such testing could be employed to make decisions regarding whether to recharge the system. The actual recharging could be initiated in response to a command entered from

a location remote from the system or from a control or calculating device co-located with the system.

It would be useful for checking of the condition of the cooling system to be conducted automatically with a capability to replenish refrigerant when a need for replenishment is indicated.

It would also be useful for checking of the condition of the cooling system to be conducted from a location remote from the cooling system.

Attempts have been made to simplify checking charge of refrigerant in cooling systems. U.S. Patent 6,308,523 to Scaringe for "Simplified Subcooling or Superheated Indicator and Method for Air Conditioning and Other Refrigeration Systems", issued October 30, 2001 (hereinafter referred to as "Scaringe"), discloses an indicator that can be attached to a pipe at an appropriate location in a cooling system. The indicator uses temperature-indicating crystals or a thermometer to show the superheat or subcooling of the system without requiring saturation curves or tables. The indicator can be scaled between a selected maximum and minimum pressure and laid out so that the corresponding saturation temperature for respective pressure intervals is indicated by the temperature-indicating crystals or thermometer. Scaringe proposes measuring evaporator exit air temperature or condenser inlet air temperature to approximate saturation temperature in the evaporator or the condenser. In any event, Scaringe requires arranging temperature indicating devices to represent a scale of the saturation temperatures of pressures within a predetermined maximum and minimum pressure.

U.S. Patent Application Publication US2003/0182958 by Mei at al. for "Non-Intrusive Refrigerant Charge Indicator", published October 2, 2003 (hereinafter referred to as "Mei"), discloses measuring temperature at an outside surface of a two-phase refrigerant line section, and using complicated third-order calculations, tables or charts to convert the measured temperature to a refrigerant pressure within the line section.

Neither Scaringe nor Mei have much reduced the complexity involved in evaluating operation of a compression cooling system. Nor do either Scaringe or Mei, individually or in any combination, contribute to remote automatic control and recharging of a cooling system.

There is a need for a compression cooling system and method for evaluating operation thereof that permits a serviceman to straightforwardly check the condition of the cooling system without having to breach the system and risk losing refrigerant.

There is also a need for a compression cooling system and method for evaluating operation thereof that permits checking of condition of the cooling system to be conducted automatically with a capability to replenish refrigerant when a need for replenishment is indicated.

There is also a need for a compression cooling system and method for evaluating operation thereof that permits checking of condition of the cooling system to be conducted from a location remote from the cooling system.

## SUMMARY OF THE INVENTION

A method for evaluating operation of a compression cooling system includes the steps of: (a) in no particular order: (1) measuring a first temperature of the refrigerant in a saturated state; and (2) measuring a second temperature of the refrigerant in a liquid state; and (b) calculating a difference between the first temperature and the second temperature to determine the extant amount of subcooling to which the refrigerant is subjected.

A compression cooling system includes: (a) a compressor, an evaporator and a condenser fluidly coupled by a fluid carrying line containing a refrigerant; (b) a first temperature measuring device connected with the system for measuring a first temperature of the refrigerant in a saturated state; and (c) a second temperature measuring device connected with the system for measuring a second temperature of the refrigerant in a liquid state.

It is therefore an object of the present invention to provide a compression cooling system and method for evaluating operation thereof that permits a serviceman to straightforwardly check the condition of the cooling system without having to breach the system and risk losing refrigerant.

It is a further object of the present invention to provide a compression cooling system and method for evaluating operation thereof that permits checking of condition of

the cooling system to be conducted automatically with a capability to replenish refrigerant when a need for replenishment is indicated.

It is yet a further object of the present invention to provide a compression cooling system and method for evaluating operation thereof that permits checking of condition of the cooling system to be conducted from a location remote from the cooling system.

Further objects and features of the present invention will be apparent from the following specification and claims when considered in connection with the accompanying drawings, in which like elements are labeled using like reference numerals in the various figures, illustrating the preferred embodiments of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram illustrating a compression cooling system configured according to the present invention.

FIG. 2 is a flow diagram illustrating the method of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic diagram illustrating a compression cooling system configured according to the present invention. In FIG. 1, a cooling system 10 includes a compressor 12, an evaporator 14 and a condenser 16. A fluid line 18 fluidly couples evaporator 14 with compressor 12. A fluid line 20 fluidly couples compressor 12 with condenser 16. A fluid line 22 fluidly couples condenser 16 with an expansion valve 24. A fluid line 26 fluidly couples expansion valve 24 with evaporator 14. By "fluidly couples" it is meant that fluid flows substantially freely within fluid lines 18, 20, 22, 26 to transport refrigerant (not shown separately in FIG. 1) among evaporator 14, condenser 112, condenser 16 and expansion valve 24. A blower fan 28 draws air across evaporator 14 generally in the direction indicated by arrow 30. A blower fan 32 draws air across condenser 16 generally in the direction indicated by arrow 34.

A building wall 40 bounds a building interior space 42 that is cooled by cooling system 10. Preferably, evaporator 14 and blower fan 28 are situated within building interior space 42. Expansion valve 24 may also be situated within building interior space 42, if desired.

A control unit 44 is configured to include a calculating device (not shown in detail in FIG. 1) and is coupled to a thermostat 46 located in building interior space 42. Other monitoring capabilities may also be carried out by control unit 44, such as monitoring temperature or air flow near blower fan 32, as indicated by a monitoring line 48.

Refrigerant is provided to compressor 12 at a compressor intake 50. Compressed refrigerant is output or exhausted by compressor 12 at a compressor exhaust 52. Compressed refrigerant proceeds from compressor exhaust 52 to condenser intake 54. Refrigerant condenses within condenser 16 to a saturated condition within condenser 16 and is further subcooled below saturation condition of the refrigerant. Refrigerant is exhausted from condenser 196 at a condenser exhaust 56 in a liquid state and traverses fluid line 22 to expansion valve 24. Refrigerant leaves expansion valve 24 via fluid line 26 and enters evaporator 14. Blower fan 28 draws cold air from about an evaporator coil 15 in evaporator 14 to provide cool air to building interior space 42. Refrigerant is exhausted from evaporator 14 via fluid line 18 to return to compressor intake 50.

When cooling system 10 is properly charged with refrigerant, refrigerant arriving at condenser intake 54 is 100% in a vapor state. Condenser 16 includes a condenser coil 17 that presents a plurality of fluid line loops for refrigerant to traverse en route to condenser exhaust 56. As refrigerant traverses condenser coil 17 from condenser intake 54 to condenser exhaust 56, refrigerant condenses and becomes saturated. Depending upon the amount of refrigerant present (i.e., the refrigerant charge) in cooling system 10, refrigerant may condense from 100% vapor (at condenser intake 54) and desuperheat to begin condensing somewhere in the region of locus 55 in condenser coil 17. The term "superheat" refers to warming of a refrigerant to a temperature above saturation temperature $T_{SATURATION}$. To desuperheat is to cool to a temperature less than or equal to saturation temperature $T_{SATURATION}$.

The amount of charge in cooling system 10 may vary the locus at which condensation occurs in condenser coil 17 toward condenser intake 54 or toward condenser exhaust 56. Refrigerant leaving condenser 16 at condenser exhaust 56 is 100% in a liquid state, and is at a temperature lower than temperature of saturated refrigerant in the interior coils of condenser coil 17. That is, at a locus in condenser coil 17 proximal to condenser exhaust 56 (e.g., locus 57), refrigerant traversing condenser coil 17 begins subcooling (i.e., cooling to a temperature below the temperature of saturated refrigerant in the interior of condenser coil 17). The amount of charge in cooling system 10 may vary the locus at which subcooling begins toward condenser intake 54 or toward condenser exhaust 56. The point to note here is that there is an interior portion of condenser coil 17 in which refrigerant is always saturated. By way of example and not by way of limitation, a saturation-assured portion 58 of condenser coil 17 is established between loci 55, 57.

Installing a temperature sensing device 60 in saturation-assured portion 58 assures that temperatures measured by temperature sensing device 60 are indicating saturated temperature ($T_{SATURATED}$) of refrigerant within cooling system 10. Installing a temperature sensing device 62 between condenser exhaust 56 and expansion valve 24 assures that temperatures measured by temperature sensing device 62 are indicating liquid temperature ($T_{LIQUID}$) of refrigerant within cooling system 10. It is preferred that temperature sensing device 62 be placed as close to condenser exhaust 56 as possible.

Subcooling is defined in a compression cooling system as the difference between saturated temperature and liquid temperature of refrigerant in the cooling system. That is,

$$\text{SUBCOOLING} = T_{SATURATED} - T_{LIQUID} \qquad [1]$$

As mentioned earlier herein, a serviceman nowadays measures pressure in fluid lines in a cooling system and consults tables, charts or similar references to determine saturation temperature $T_{SATURATED}$. In contrast, the present invention contemplates using subcooling as the primary indicator by which a one may evaluate operation of a compression cooling system, without requiring any complex conversion, calculation or consulting of references to determine another parameter for use in evaluating the

operation of the cooling system. Using the apparatus and method of the present invention, one may read temperature from temperature sensing devices 60, 62 and use expression [1] to simply and straightforwardly ascertain the extant level of subcooling effected by cooling system 10. If the extant level of subcooling is less than a predetermined acceptable level of subcooling (provided, by way of example and not by way of limitation, by a reference book, posted on a cabinet containing cooling system 10, or stored in control unit 44), then refrigerant may be introduced into a fluid line 18, 20, 22, 26 while observing variance of saturation temperature $T_{SATURATION}$ and liquid temperature $T_{LIQUID}$. Expression [1] may be employed to straightforwardly dynamically monitor and control adding refrigerant to achieve a desired level of subcooling that has been established as indicating a properly operating cooling system.

Coupling temperature sensing devices 60, 62 to control unit 44, for example, provides a capability for automatically effecting checks of subcooling. Control unit 44 may include a calculating device and a memory storage (not shown in detail in FIG. 1) for treating indications received from temperature sensing devices 60, 62 using expression [1], ascertaining whether the extant level of subcooling thereby determined is at least equal with a predetermined acceptable level of subcooling stored in memory in control unit 44. If the extant level of subcooling indicates a need for adding refrigerant, a control signal may be automatically sent from control unit 44 to a valve control unit 70. Communication with valve control unit 70 by control unit 44 may be carried out via a wired connection or via wireless connection, as indicated at connection locus 72. Valve control unit 70 responds to signals from control unit 44 to open valve 74 so that refrigerant may flow from a refrigerant reserve or reservoir 75 to fluid line 20 (other fluid lines 18, 22, 24 may be used for refrigerant addition if desired).

Control unit 44 may be co-located with cooling system 10. Alternatively, control system 44 may be remotely co-located from cooling system 10 (not shown in FIG. 1). In yet another alternate configuration, control unit 44 may be co-located with cooling system 10 but may be communication with a remote station (not shown in FIG. 1) and respond to commands from the remote station. Communication among control unit 44, valve control unit 70 and a remote location (if provided) may be carried out via a wired connection or

via wireless connection (as indicated at connection locus 72). Evaluation of operation of cooling system 10 may be carried out from the remote location. Refrigerant may be added on command from the remote location if desired. Alternatively, cooling system 10 may be configured to permit return of refrigerant to reservoir 75 when control unit 44 determines that subcooling has cooled the refrigerant to too cool a temperature.

FIG. 2 is a flow diagram illustrating the method of the present invention. In FIG. 2, a method 100 for evaluating operation of a compression cooling system begins at a START locus 102. Method 100 continues with the step of, in no particular order, (1) measuring a first temperature of the refrigerant in a saturated state, as indicated by a block 104; and (2) measuring a second temperature of the refrigerant in a liquid state, as indicated by a block 106.

Method 100 continues with the step of calculating a difference between the first temperature and the second temperature to determine the extant amount of subcooling to which the refrigerant is subjected, as indicated by a block 108.

Method 100 may continue with the step of posing a query whether the extant amount of subcooling is less than a predetermined acceptable amount of subcooling, as indicated by a query block 110. If the extant amount of subcooling is less than the predetermined acceptable amount of subcooling, method 100 continues via YES response line 112 and refrigerant is added to the cooling system, as indicated by a block 114. Method 100 thereafter returns to a locus 115 from which method 100 proceeds to carry out method steps indicated by blocks 104, 106, 108, 110.

If the extant amount of subcooling is not less than the predetermined acceptable amount of subcooling, method 100 continues via NO response line 116 and method 100 terminates at an END locus 118.

It is to be understood that, while the detailed drawings and specific examples given describe preferred embodiments of the invention, they are for the purpose of illustration only, that the apparatus and method of the invention are not limited to the precise details and conditions disclosed and that various changes may be made therein without departing from the spirit of the invention which is defined by the following claims: